ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Report On

PROJECT NO. 16 - EFFECT OF INSULATION OF TRANSMISSION AND FINAL DRIVE UPON THE HEAT LOAD WITHIN TANKS

Project No. 16

4 February 1944

ARMORED MEDICAL RESEARCH LABORATORY
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724-1 GNOML

1. PROJECT: No. 16 - Effect of Insulation of Transmission and Final Drive Upon the Heat Load Within Tanks.

a. Authority - Reference second indorsement Headquarters Army Ground Forces, file 470.8 (R) (13 Sept 43) GNRQT-10/54367, dated 21 Sept. 1943, subject: Tests of Transmission and Final Drive Insulation for Medium Tank M4A3.

b. Purpose - To determine the benefits, from the standpoint of reduction of heat load imposed upon tank crews, resulting from insulation of the transmission and final drive in the M4 Series Medium Tanks.

2. DISCUSSION:

a. The heat given off from the hot surfaces (150°F and higher) of the transmission and final drive housings in the bow of the M4 tank is an important contribution to the total heat load imposed upon tank crew members, especially the driver and bow gunner. In areas where the ambient temperature and humidity is near the limit of human tolerance, the additional heat contributed by the transmission and drive may render the atmosphere inside the tank wholly intolerable from the standpoint of effective crew performance. The subject insulating blanket was developed for the purpose of reducing the heat contributed by this source in existing tanks.

b. Procedure: Owing to the fact that the blanket was received late in the year it was not possible to conduct physiological tests to measure directly the benefits to the crew resulting from the reduction in heat load. Comparative tests have been carried out, however, to determine approximately the relative amounts of heat given off by the transmission and final drive, with and without the insulation. Details of test procedure and discussion of the results are given in the appendix.

3. CONCLUSION:

a. The insulating blanket reduced the rate of heat transfer from the transmission and final drive by approximately 30%.

b. The average air temperature in the bow was 7°F lower with the blanket installed than in the standard vehicle.

c. The average temperature of the insulated surfaces was 86°F as compared with 143°F in the case of the bare metal housing.

d. Use of this blanket results in sufficient improvement to warrant its adoption. The tests indicate greater improvement is possible through improved design.

4. RECOMMENDATIONS:

a. That an insulation blanket be considered satisfactory for use in M4 Medium Tanks operating in areas where high ambient temperatures and humidity exist.

b. That installation of insulating blankets be made at intermediate tank depots for all tanks being shipped to the South, Central and Southwest Pacific Theatres.

c. That the blanket be designed for easy installation and removal and provided with surface protection against absorption of oil, water and chemical warfare agents.

d. That the possibility of further improvement in blanket design be investigated.

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APPROVED Willard Machle
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Colonel, Medical Corps
Commanding

3 Incls.
#1 - Appendix
#2 - Tables 1 & 2
#3 - Figs. 1 thru 7

APPENDIX

1. Procedure.

a. Tank Operation: The following operating procedure was employed in each of six tests, three with the normal standard tank and three with the insulating blanket installed in the same tank: The tank was driven over the highway and on the range with the transmission oil radiator in the bulkhead covered, in order to heat up the transmission and final drive mechanism quickly. When the transmission oil temperature was raised to approximately 180°F, the tank was returned to the Laboratory, the cover over the radiator removed and the engine allowed to idle at 500 RPM for approximately 2 hours with the tank hatches closed and turret and rear mushroom ventilators plugged.

b. Temperature Measurements: During the 2 hour period the following temperatures were recorded: oil temperature leaving and returning to the transmission, surface temperatures of final drive (left and right) and transmission housings* inside armor temperature (bow roof), outside air and air just before leaving through bulkhead radiators. During two pairs of tests two oscillating table fans were operated in the tank which mixed the air thoroughly in order to obtain a good average leaving air temperature. In the remaining pair of tests without mixing fans, two observers inside the tank recorded air temperatures at the five crew positions. These last temperatures and the outside temperature were measured by thermometer; all others were obtained with calibrated chromel-alumel thermocouples.

c. Calculation of Heat Transfer. The rate of ventilation through the crew compartment of the tank employed in these tests, previously determined by the gas-dilution method, was 300 cfm at 500 RPM engine speed. With this value and the rise in temperature of the air passing through the crew compartment it was possible to calculate, in part, the amount of heat given off by the transmission and final drive. No attempt was made to estimate the portion of input heat which was lost through the tank walls.

2. Results.

The resulting temperature records for the six tests shown in Figures 1 to 6.

a. Comparative Heat Transfer. Comparative heat transfer rates, as measured by rise in air temperature, are given in Table 1. The heat transfer from the uninsulated surfaces was 38% higher than with the blanket installed. To this improvement must be added the unestimated additional heat dissipated through the tank walls which, in the case of the uninsulated tank, was the greater and would further improve the comparative benefit of the insulating blanket. It is important to note that under the conditions of these tests,

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* Temperatures of metal and insulation surfaces in the respective tests.

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the rate of heat transfer per unit of temperature difference from the outside blanket surface to the ambient air was markedly greater than the corresponding rate per unit temperature difference in the case of the bare metal surface. Thus, the effectiveness of the blanket is not as great as would be expected from theoretical considerations.

b. Comparative Air and Surface Temperatures. The average excess air temperature in the bow crew position over outside ambient temperature was 20°F and 27°F for the standard and insulated vehicles, respectively. The average surface temperatures, in the same order, were 86°F and 143°F. Thus, in terms of the heat load which would be imposed upon the bow crew members, a marked improvement is effected by the insulative blanket. The radiation load is strikingly reduced and the 7°F reduction in air temperature, when considered in relation to high ambient temperatures, represents a substantial benefit. At an ambient of 90°F, for example, a reduction of inside temperature from 117°F to 110°F leads to a decrease of one-third in individual heat gain from the hot surrounding air.

c. Comparative Oil-Cooling Rates. The rates of reduction of transmission oil temperatures for the bare and insulated transmission and final drive assemblies are shown in Table 2 and Fig. 7. No significant differences will be noted. It may be assumed from this that the amount of heat dissipated at the oil radiator is so great compared with that given off from the housing that the reduction in heat transfer from the housing effected by the blanket does not markedly affect the overall cooling.

3. Conclusion.

These tests measure the physiological improvement which is brought about by insulation of the transmission and final drive housings only indirectly. The reduction in heat transfer and the lowering of air temperature and radiation temperature, when translated into terms of high ambient condition, represent significant improvement. It is pointed out, however, that the degree of improvement in the present instance does not appear to be as great as would be expected from theoretical considerations, and further study of the design of the blanket is suggested in order to secure the maximum benefit.

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TABLE 1

SUMMARY OF HEAT TRANSFER RATES

	No Blanket	With Blanket
Air temp. rise	18.7°F	13.4°F
Oil Temp. differential	116°F	115°F
Air temp. rise/100° Oil Temp. diff.	16.1°F	11.6°F
Heat transfer to air	5800 Btu/hr.	4200 Btu/hr.

Incl. #2

TABLE 2

RELATIVE COOLING RATES OF TRANSMISSION OIL

TIME (Min)	TEMPERATURE RELATIVE TO INITIAL LEVEL			
	NO INSULATION		WITH INSULATION	
	(Fans)	(No Fans)	(Fans)	(No Fans)
0	1.0	1.0	1.0	1.0
20	0.915	0.935	0.92	0.93
40	0.85	0.88	0.86	0.88
60	0.78	0.825	0.81	0.83
80	0.73	0.77	0.76	0.79
100	0.69	0.73	0.73	0.75
Aver. Rate: $\frac{\Delta T/Hr}{T}$	0.24	0.19	0.20	0.17

Incl. #2

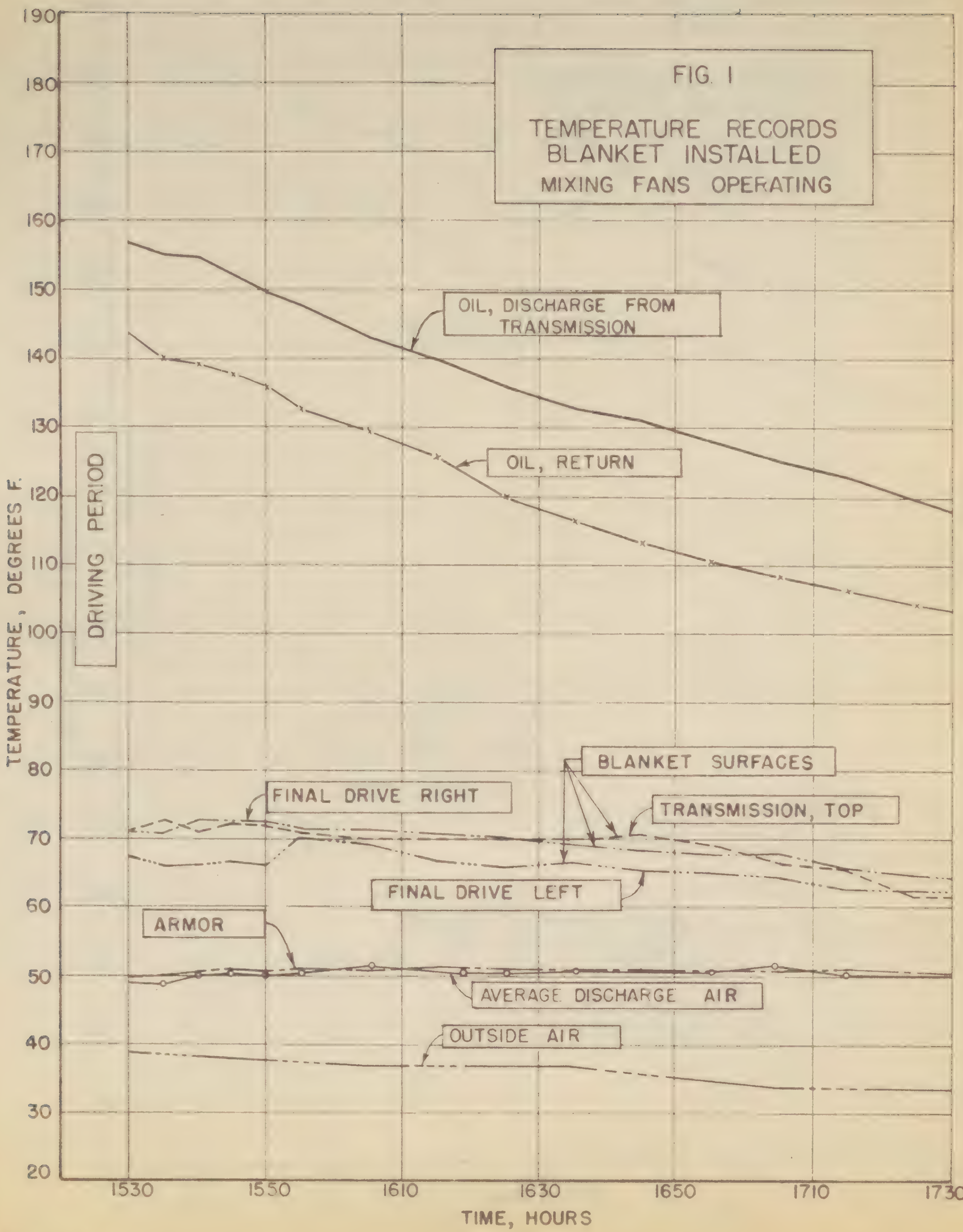

FIG. I
TEMPERATURE RECORDS
BLANKET INSTALLED
MIXING FANS OPERATING
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
TEMPERATURE, DEGREES F.
DRIVING PERIOD
OIL, DISCHARGE FROM TRANSMISSION
OIL, RETURN
BLANKET SURFACES
FINAL DRIVE RIGHT
TRANSMISSION, TOP
FINAL DRIVE LEFT
ARMOR
AVERAGE DISCHARGE AIR
OUTSIDE AIR
1530
1550
1610
1630
1650
1710
1730
TIME, HOURS

FIG. I

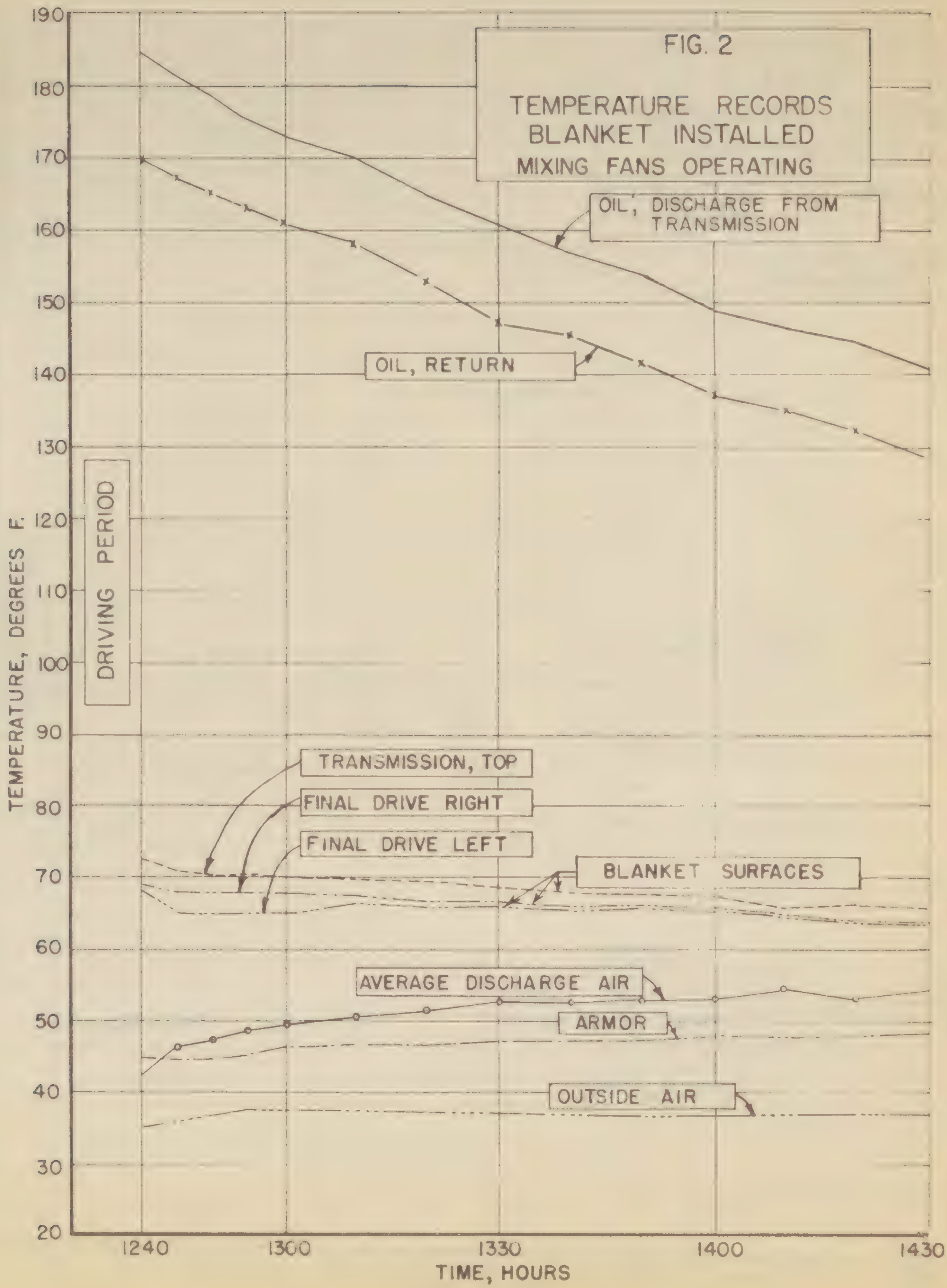

FIG. 2
TEMPERATURE RECORDS
BLANKET INSTALLED
MIXING FANS OPERATING
OIL, DISCHARGE FROM TRANSMISSION
OIL, RETURN
DRIVING PERIOD
TRANSMISSION, TOP
FINAL DRIVE RIGHT
FINAL DRIVE LEFT
BLANKET SURFACES
AVERAGE DISCHARGE AIR
ARMOR
OUTSIDE AIR
TEMPERATURE, DEGREES F.
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1240
1300
1330
1400
1430
TIME, HOURS

FIG. 2

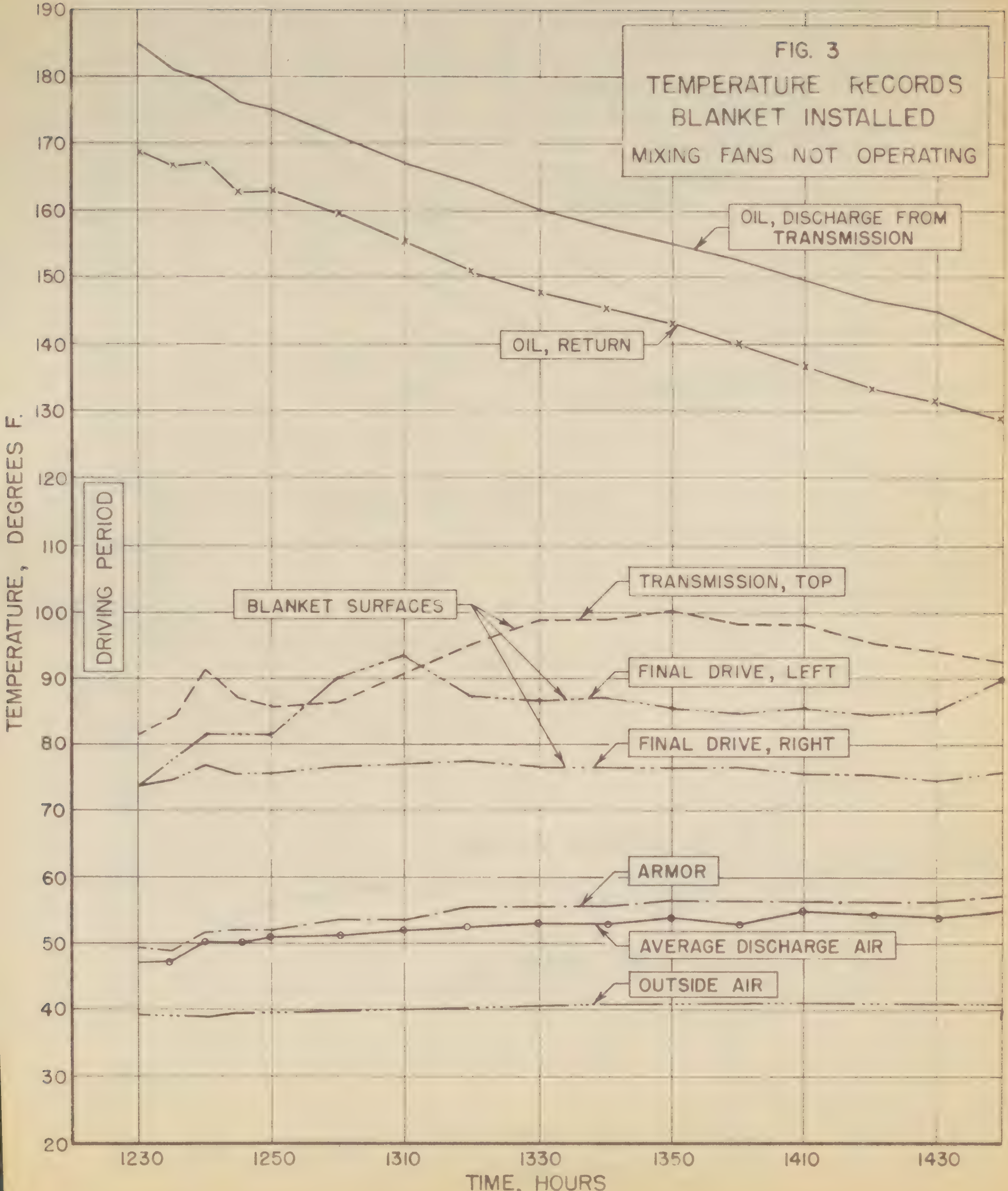
FIG. 3
TEMPERATURE RECORDS
BLANKET INSTALLED
MIXING FANS NOT OPERATING
OIL, DISCHARGE FROM TRANSMISSION
OIL, RETURN
DRIVING PERIOD
BLANKET SURFACES
TRANSMISSION, TOP
FINAL DRIVE, LEFT
FINAL DRIVE, RIGHT
ARMOR
AVERAGE DISCHARGE AIR
OUTSIDE AIR
TEMPERATURE, DEGREES F.
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1230
1250
1310
1330
1350
1410
1430
TIME, HOURS

FIG. 3

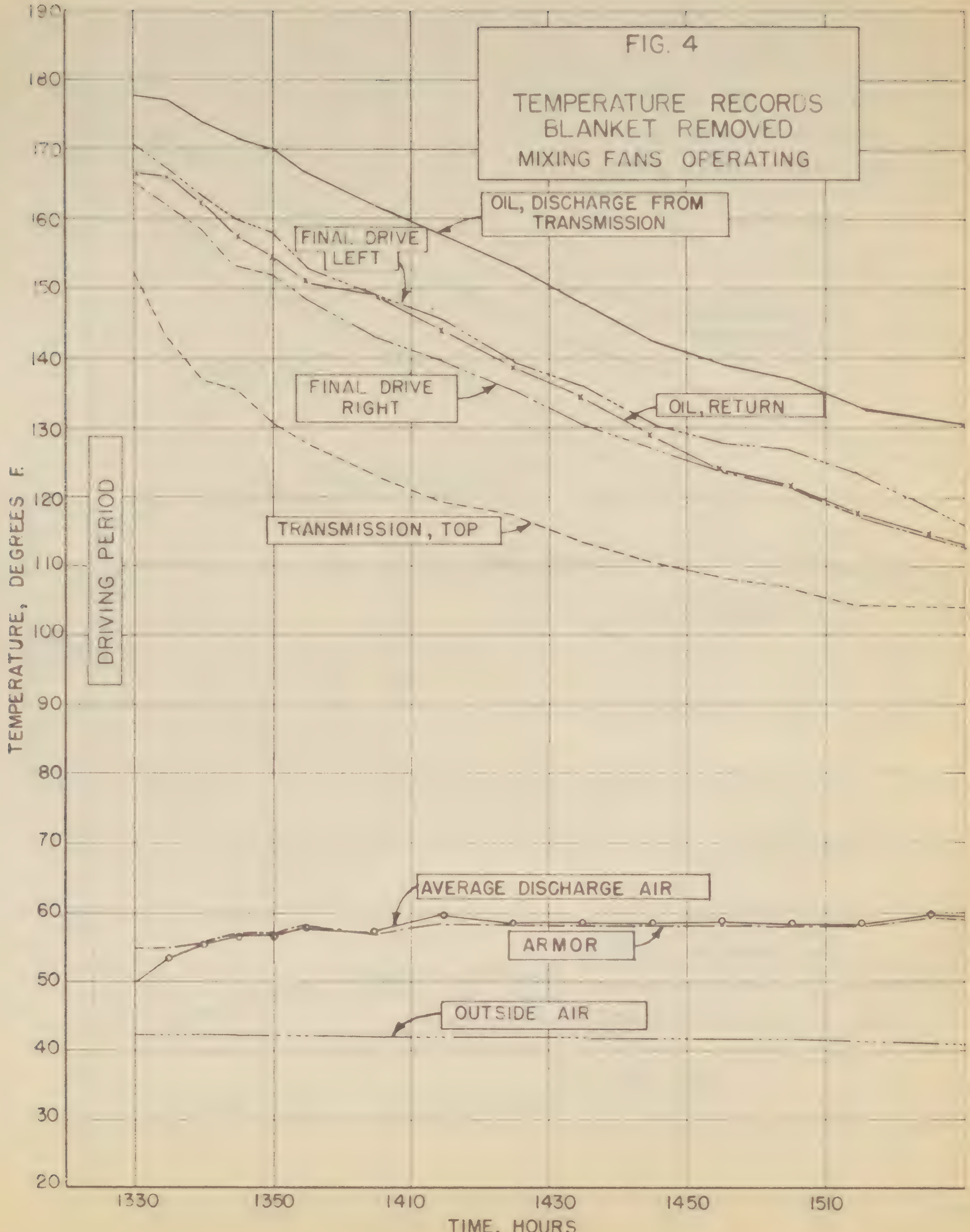
FIG. 4
TEMPERATURE RECORDS
BLANKET REMOVED
MIXING FANS OPERATING
OIL, DISCHARGE FROM TRANSMISSION
FINAL DRIVE LEFT
FINAL DRIVE RIGHT
OIL, RETURN
TRANSMISSION, TOP
DRIVING PERIOD
AVERAGE DISCHARGE AIR
ARMOR
OUTSIDE AIR
TEMPERATURE, DEGREES F
TIME, HOURS
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1330
1350
1410
1430
1450
1510

FIG. 4

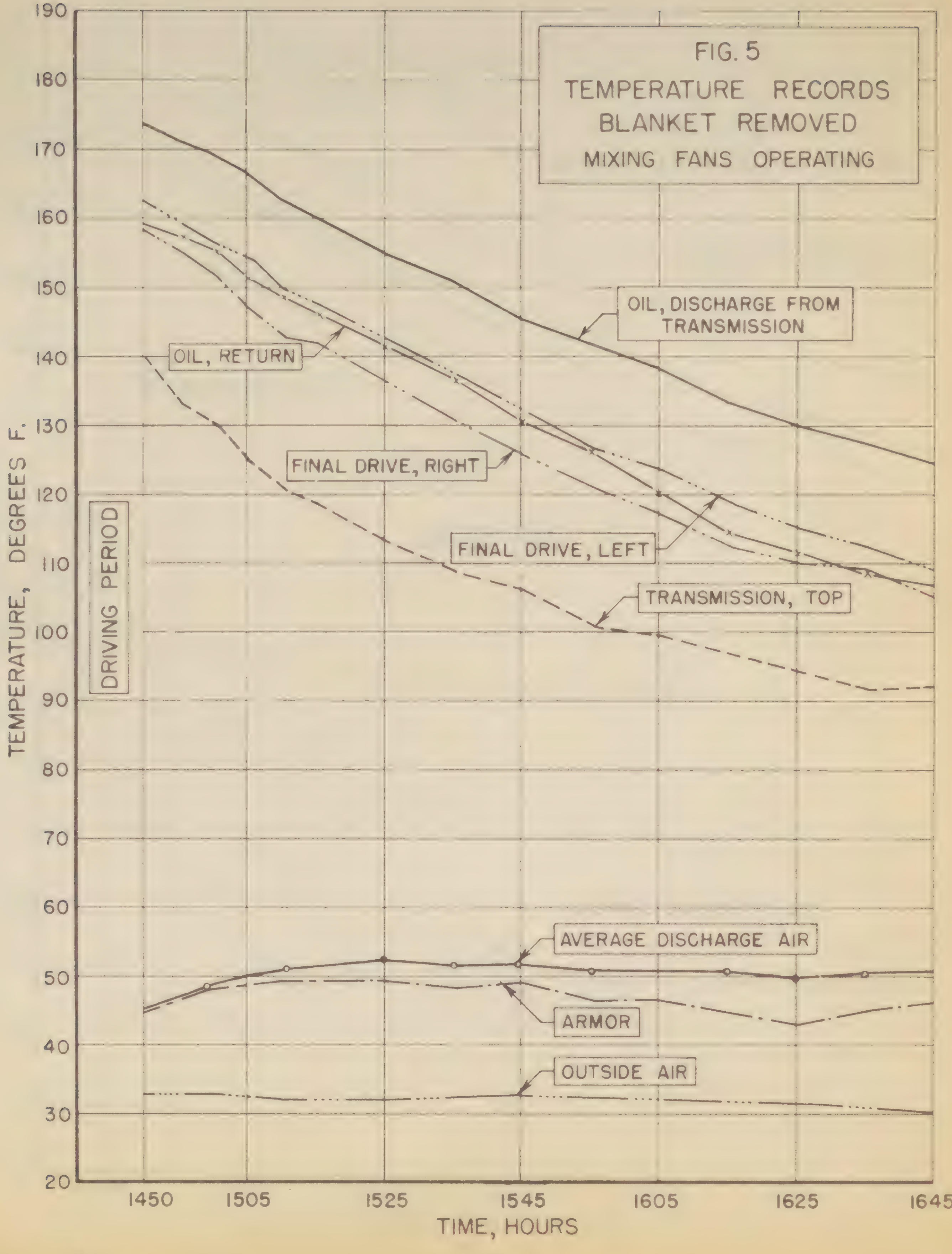

FIG. 5
TEMPERATURE RECORDS
BLANKET REMOVED
MIXING FANS OPERATING
OIL, DISCHARGE FROM TRANSMISSION
OIL, RETURN
FINAL DRIVE, RIGHT
FINAL DRIVE, LEFT
TRANSMISSION, TOP
DRIVING PERIOD
AVERAGE DISCHARGE AIR
ARMOR
OUTSIDE AIR
TEMPERATURE, DEGREES F.
TIME, HOURS
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1450
1505
1525
1545
1605
1625
1645

FIG. 5

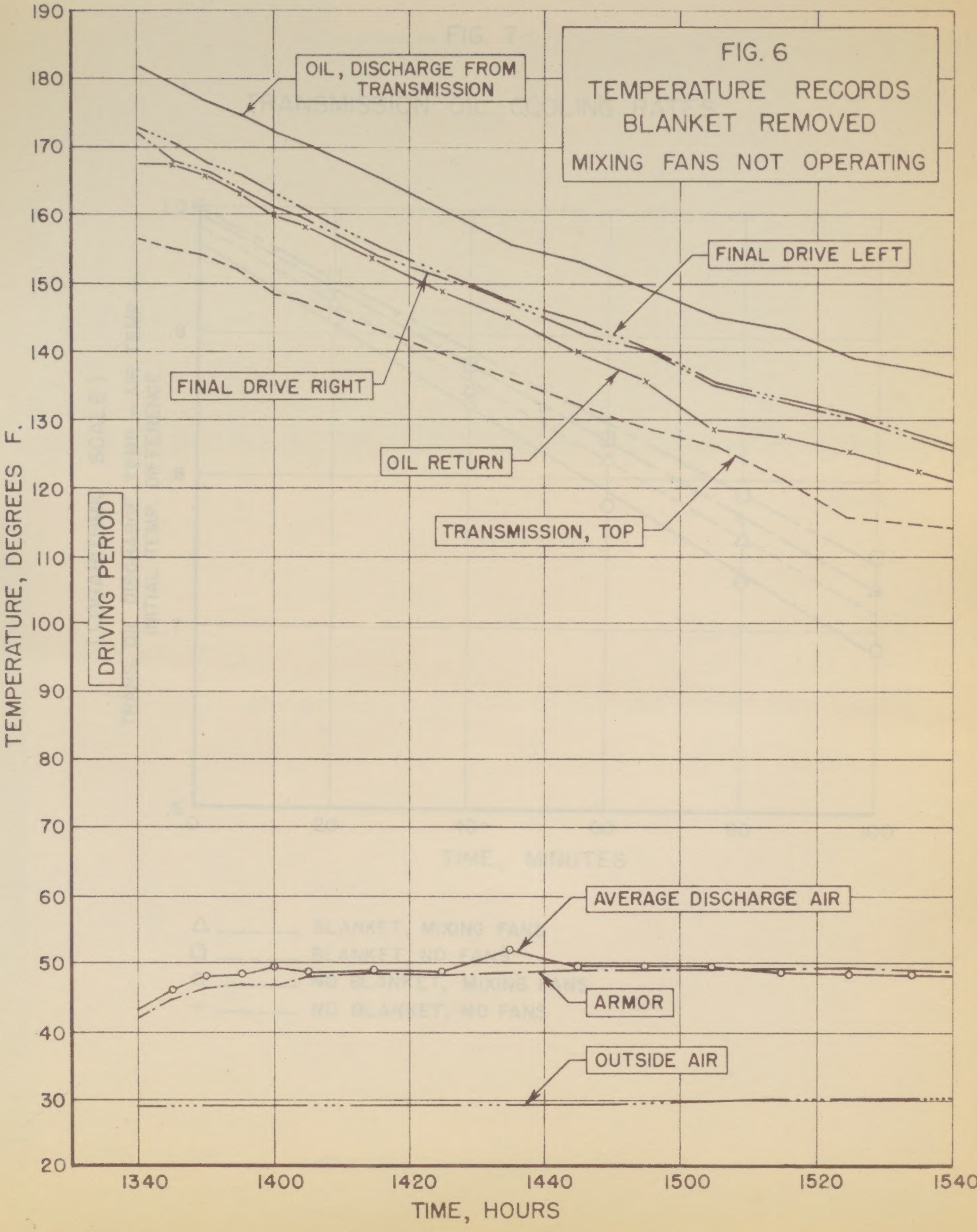
FIG. 6
TEMPERATURE RECORDS
BLANKET REMOVED
MIXING FANS NOT OPERATING
OIL, DISCHARGE FROM TRANSMISSION
FINAL DRIVE LEFT
FINAL DRIVE RIGHT
OIL RETURN
TRANSMISSION, TOP
AVERAGE DISCHARGE AIR
ARMOR
OUTSIDE AIR
DRIVING PERIOD
TEMPERATURE, DEGREES F.
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
1340
1400
1420
1440
1500
1520
1540
TIME, HOURS

FIG. 6

FIG. 7

TRANSMISSION OIL COOLING RATES

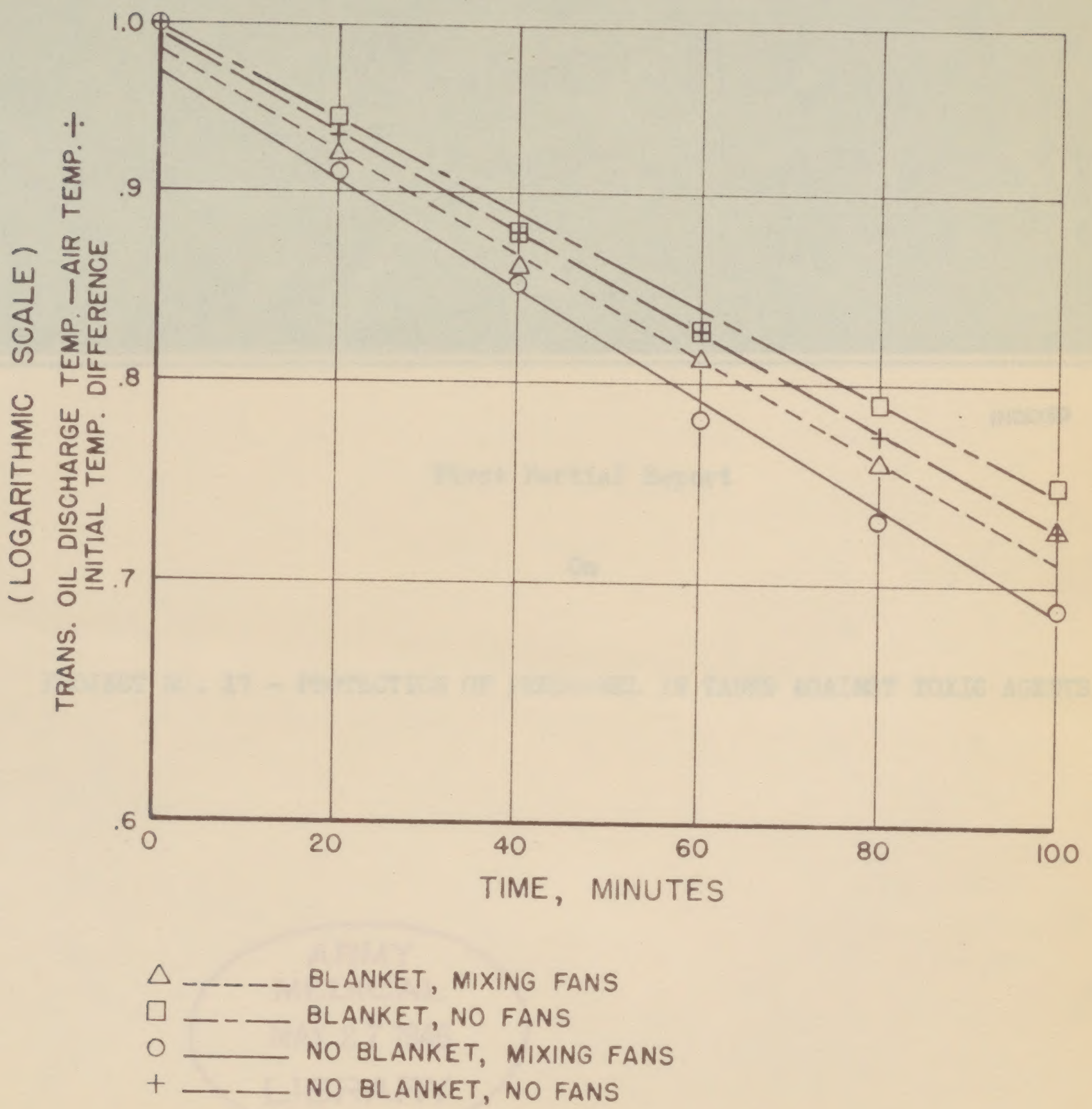

FIG. 7